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ABSTRACT

This report reviews the literature on instructional graphics and implications of the findings in terms of graphic displays for computer assisted instruction. It was concluded that assumptions about the inherent value of graphics for instructional purposes are unsubstantiated by empirical evidence, and the conditions under which the use of graphics may increase instructional effectiveness remain to be determined. Comparisons between alphanumeric and graphic displays and between different graphic representations suggest that future research should systematically explore the use of graphics as a function of task requirements, subject matter content, and learner characteristics. The research also suggests that the interpretation of research outcomes is contingent upon the dependent measures obtained and that particular attention should be given to measures of delayed retention. (Author)

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Technical Paper 332

THE EDUCATIONAL EFFECTIVENESS OF GRAPHIC DISPLAYS FOR COMPUTER ASSISTED INSTRUCTION

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FOREWORD

The Educational Concepts and Evaluation Work Unit Area of the Army Research Institute (ARI) performs research and development in areas of educational technology with applicability to military training. Of special interest is research in the area of large-scale, computer-based instructional systems. Development and implementation of such systems is seen as a solution to such current Army training problems as shortages of qualified instructor personnel, student populations of widely varying abilities, and increased training costs.

Technological advances in computer technology now make it possible to use sophisticated graphics techniques in the instructional process. Although it has been assumed that such techniques will improve training effectiveness, scientific evidence does not consistently support this viewpoint. This paper is the result of the first phase of an in-house research and exploratory project investigating the effectiveness of instructional graphics in computer-based instructional systems.

The effort was initiated in the Unit Training and Evaluation Systems Technical Area in response to the requirements of Army Project 2Q763731A762, "Computer Administered Instruction," FY 1975 Work Program, and was continued under Army Project 2Q762717A764, "Automated Educational Technology and Training Simulation," FY 1976 Work Program. The work unit area has since been transferred to the Educational Technology and Simulation Technical Area of ARI.

JOSEPH ZEIDNER
Technical Director

THE EDUCATIONAL EFFECTIVENESS OF GRAPHIC DISPLAYS FOR COMPUTER-ASSISTED INSTRUCTION

BRIEF

Requirement:

To determine the current state-of-the-art for the use of graphics in the instructional process and to specify critical research gaps, particularly with respect to computer graphics.

Procedure:

A review of the literature related to the use of instructional graphics was conducted. Research findings were analyzed in terms of the degree to which they did or did not support theoretical assumptions and propositions concerning the instructional value of graphics.

There is considerable question as to the instructional effectiveness of graphics in general. Given the cost of graphics relative to less sophisticated presentations, a substantial effort should be directed toward specifying the conditions in which graphics may be effectively employed. Three major factors substantially influence the effectiveness of graphics: task requirements, subject-matter content, and learner characteristics.

Utilization of Findings:

This review resulted in an in-house plan to empirically examine instructional graphics through a series of experiments using a range of tasks, subject matter, and measured student characteristics typically encountered in an Army training environment.

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THE EDUCATIONAL EFFECTIVENESS OF GRAPHIC DISPLAYS FOR COMPUTER ASSISTED INSTRUCTION

INTRODUCTION

The impact of computers on the educational community over the last 5 years is self-evident. Even the casual observer cannot fail to note the substantial increase in the number of articles, journals, professional organizations, and industrial brochures devoted to computer-based instruction.[1] It is hardly surprising that the military, with its heavy commitment to education and training, has been among the leaders in the evaluation and development of computer instruction. The extent of this effort has been well-documented elsewhere and is not addressed in this report (Fletcher, 1975; Rich & Van Pelt, 1974).

What is surprising, however, is that a survey of the Army training establishments indicates a greater degree of optimism among potential users of computer instruction than among members of the research community (Sherron, 1976). In effect, Sherron found that the users (the faculty and staff of Army training organizations) anticipate that operational implementation of computers in the instructional setting will occur much earlier than the time forecast by the research and development community. This discrepancy may exist because those engaged in research and development recognize that the initial financial investment required for computer-based instruction is likely to be substantial. In addition, the conditions under which computer instruction can enhance training effectiveness remain to be accurately determined.

The introduction of a new technology requires a careful reassessment of the relationship between cost and expected gains in performance resulting from the technology. In the case of computers, this reassessment is especially difficult, because certain of the capabilities uniquely provided by computers permit the introduction of techniques previously impossible or even unknown. Although the performance value gained by using these unique capabilities has never been evaluated, they are most likely to be most costly. This paper is concerned with one of these capabilities, specifically the ability to rapidly generate and modify sophisticated graphic displays. This capability is of particular interest when the computer is directly employed to present instructional material--computer-assisted instruction (CAI).

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[1]Computer-based instruction is the generic term encompassing the use of the computer for the administration, management, and presentation of instruction.

The emphasis on CAI display capabilities is not purely arbitrary. One of the major costs of CAI is that of the input-output devices, i.e., student/instructor terminals. The best estimate we have is that, for a multiterminal CAI system, approximately 50% of the initial investment is for the terminals and supportive software to drive them. Moreover, a major factor in terminal cost is the degree of display sophistication required. Hence, the decisionmaker concerned with allocating resources in the development of a CAI system must carefully determine the display requirements of the system. The following succinctly summarizes the situation:

> ". . . questions to consider are: Will the user need to portray motion graphically? Is high accuracy of the drawing needed? Are highly complex rotation and size changes required on a continuous basis? If the answer to all of these is yes, ther an elaborate and rather costly system is required. But as the user is willing to relax each of these requirements, lower cost results" (Computer Decisions, 1971, p. 41).

The problem for the decisionmaker, then, appears straightforward: Specify the system goals, determine the system characteristics that meet these goals, and then specify the hardware/software requirements that supply these characteristics. The problem is easily stated but not so easily accomplished.

In terms of Army training, the system goals are usually the training objectives. A critical assumption is that the objectives are meaningful and have been evaluated in an acceptable manner. If the system objectives do not relate to desired performance then, of course, the system will be ineffective. Fortunately for education and training research, the researcher may develop principles, in terms of generally stated objectives or tasks, in parallel with the specification of objectives in terms of specific behaviors or tasks.

Leaving the question of determining system characteristics until last, consider the question of specifying the hardware/software requirements that provide desired system characteristics. This problem is relatively easy to solve, as the literature abounds in relevant information (Colson, Freeman, Mathews, Stettler, 1974; Kuehn, 1966; Machover, 1966; Miller, 1969; Weitzman, 1973). Although much of this work deals with performance rather than training systems, such a distinction poses no difficulty at a molar level of specification.

Finally, consider the determination of system characteristics. It is here that serious problems may exist. A major activity of educational research is to provide the data upon which to base decisions regarding those characteristics necessary to achieve system goals. To the extent that these data exist and are sufficient, the specification of system characteristics will be a relatively easy task. On the other hand, if the data are insufficient, an area needing further research has been defined. As was stated earlier, a major cost of a CAI system is for the

terminals (including special software). This cost in turn is, to a large extent, a function of the graphics capability required. Therefore, it would be useful for the CAI system designer to be able to determine

1. The degree to which a graphics capability will enhance instructional effectiveness and

2. If graphics are desirable, the level of sophistication required.

Unfortunately, if the following quotations are any indication, the information necessary to answer these questions is less than satisfactory.

> Unfortunately, research has not yielded data permitting sweeping generalizations about media. . . . Consequently, good judgment must be used in planning just how to accomplish each instructional event for the lesson plan (Gagne & Briggs, 1974, p. 151).

> The relative effectiveness of alphanumeric versus graphic displays in communicating efficiently, facilitating learning, and promoting long term retention should receive more investigation (Rigney & Lutz, 1974, p. 1).

> Despite existing folklore to the effect that one picture is worth a thousand words, there is little in the way of scientific data to support such a contention (Haygood, Leshowitz, & Parkinson, 1974, p. 3).

> Although many of us feel that pictorial information is and should be extremely important to the learning process, . . . nevertheless, when it comes to using graphic capabilities in instructional situations we seem often to proceed in bumbling fashion, relying entirely on individual intuition (Bork & Leahy, 1976, p. 3).

Clearly, there is little in the preceding quotations to encourage the decisionmaker. This gap in the state-of-the-art prompts both the subject matter and the title of this report. The remainder of the report consists of three sections. Part one, the major portion, reviews the literature to date on the instructional effectiveness of graphics, including the special problem of individual differences. The second part briefly discusses CAI research with graphics, and the third portion suggests a framework for future research.

WHERE ARE WE?

In an attempt to organize the literature on instructional graphics, two things become apparent. First, there is an implicit assumption that graphics increase the effectiveness of instruction, and second, there are a number of contentions as to the reasons for this effectiveness. Hence,

the literature that follows is organized on the basis of what might loosely be called theoretical predispositions. These positions range from contentions that intrinsic cues promote perceptual efficiency to emphasis on extrinsic motivational factors. The rationale for each position is stated, the literature relevant to the position reviewed, and a brief summary provided to indicate how well the literature supports the position.

Throughout the literature, developers of pictorial stimuli variously reason that visuals are effective because (a) they are perceived more efficiently, (b) they are realistic, (c) students prefer them, (d) they unburden overloaded channels, (e) perceptual research has shown individual differences in visual ability to be an important variable, and (f) visuals are part of a larger, more advanced instructional system. Experiments designed in part to verify these explanations have failed to support them, as will be seen in the following sections of this review. The literature related to each of these rationales is discussed in turn.

Perceptual Efficiency

The belief that visuals are perceived more readily relates to the idea that they are intrinsically better communicators and will be remembered longer because they provide referents. The concept of the intrinsic value of visuals is rather complex, but in essence it implies that pictures are perceived, encoded, decoded, and stored more naturally than are visual or auditory presentations of verbal stimuli (Paivio, 1969); hence the assumption that the perceptual or cognitive superiority of pictorial stimuli should facilitate learning: if visuals are perceived more readily than alphanumerics, they should be better teaching devices.

Eye Movement Patterns. Eye movement patterns have been identified in several studies (Brandt, 1948; Faw & Nunnally, 1967; Hess, 1965; Mackworth & Morandi, 1967). Subjects tend to fixate on complex areas of photographs where lines contour sharply (Mackworth & Morandi, 1967). However, complexity does not assure fixation. When two pictures containing attributes of complexity, novelty, and pleasantness are presented simultaneously, subject fixation increases primarily with degrees of pleasantness (Faw & Nunnally, 1967). These and other studies, particularly Hess' (1965) pupil dilation measurement, suggest that the subject matter of pictorial material, not its physical properties alone, influences the stimuli to which the learner attends.

There is some evidence that attending to stimuli more readily does not automatically assure more learning. For example, Ryan and Schwartz (1956) measured recognition time with a tachistoscope, believing that, "An illustration which required a long perception time must contain confusing or conflicting elements and therefore is less directly relevant to its purpose" (p. 60). They manipulated three types of pictorial content--hand, electrical knife, and steam engine cutaway--using four types of pictorials--photographs, shaded drawings, line drawings, and cartoons. They found that line drawings require significantly longer

and cartoons significantly shorter time to be identified. Each stimulus had also been presented in several different dimension-poses. A significant post/object interaction occurred (reminiscent of the many content-mode interactions cited in the literature). Researchers concerned with instructional effectiveness rather than perceptual efficiency report opposite findings (Dwyer, 1968a, 1968c).

Along similar theoretical lines, Rogers (1970) presented subjects with both highly alliterative and nonalliterative alphanumeric displays, believing that alliteration from one word would act as a cue for learning the other in a paired associate learning paradigm. She found, however, that until subjects were advised (in a written explanation) to use the alliteration to their advantage, alliteration did not significantly improve learning.

Color Perception. Perhaps the clearest indication that ease of perception is not sufficient to facilitate learning is the research done using color. As Brandt (1948) pointed out, color draws attention. Moreover, visual acuity may be enhanced by the juxtaposition of chromatic and achromatic stimuli; dimensionality may be conveyed by having two colors lie adjacent to each other, and they will most likely be perceived in two different planes; and color may be the major cue in the determination of the size, distance, and weight of the stimuli (Payne, 1964). Researchers who have attempted to enhance their instructional programs by adding color have been largely unsuccessful (Dwyer, 1968a, 1968d, 1968f). There are undoubtedly conditions in which color can be used as an effective instructional cue; nevertheless, the mere addition of color as an attention-getting mechanism does not guarantee instructional effectiveness.

Pictures and Associations. The idea that pictures act as referents, that they are able to be absorbed as one hermetic unit, and that this material can later be reconstructed and decoded, is persistent in the educational literature (Arnheim, 1972; Dwyer, 1972). Experiments addressing these propositions, however, have shown that a behaviorist view of learning from pictures by some sort of Thorndike-stamped-in association is simplistic and outdated. In two unusual experiments, Ketcham and Heath (1962, 1963) taught students using audiotape and slides. One group saw slides that related to the topic material, while another saw slides that were not relevant. A third group (audiotape only) acted as a control. Results indicated that the nonrelevant slide presentation did facilitate memory for the topic material better than audiotape only, although not as well as the relevant slide presentation. Likewise, the associations made to pictures are more complex than the "associative value of pictures" implies (Deno, Johnson, & Jenkins, 1968; Otto, 1962; Worth, 1968). When presented with either a list of words or successive pictorial stimuli to which subjects were asked to make nonlabeling associations, a greater similarity was found to exist between the responses made to the words (which were independent) than between the responses made to a word and the picture to which it referred (Deno et al., 1968).

Worth (1968), using Osgood's Semantic Differential (Osgood, Suci, & Tannenbaum, 1957), found that manipulation of the elements within a picture affected its interpretation. Students tended to integrate elements within a picture into a unified theme, the number of themes increasing as elements became more dissimilar. Otto (1968) also found that pictures and their verbal descriptors evoked qualitatively different responses, the responses varying according to which category they belonged. Garrard (1971) found that carefully derived sets of data, generated by a computer functioning under a stochastic model of human response behavior in a classification scheme for six physics words such as "velocity" and "momentum," produced only moderate to low correlation with actual human responses. Although it appears that pictures can act as referents, the conditions under which they do so have not yet been delineated. Hence, the instructional effectiveness of the associational value of pictures remains to be determined.

Recognition: Auditory versus Pictorial. The nature of the task employed considerably affects the relation between sensory modality and encoding efficiency (Ingersoll, 1970; Jensen, 1971). For example, recognition tasks that require the subject to monitor a stimulus have traditionally found that auditory stimuli are more accurately detected than are visual stimuli. Moreover, if the dependent measure is response latency, the auditory stimuli are responded to more quickly than are the visual stimuli (Jensen, 1971). Some theorists interpret these results as indicative of a primary auditory coding mechanism; visual inputs must first be transformed into this auditory code, hence the longer response latency. Similarly, female students who were required to count the frequency of oncoming stimuli that were grouped both successively and simultaneously (totaling 6,192 decisions per subject) processed the auditory stimulus (a sharp click) more effectively than the visual (a flash) or the tactile (pressure to the forefinger) when the stimuli were presented successively. As speed of transmission increased, visual and tactile accuracy decreased sharply (Reese, Robinson, Stevenson, & Volkman, 1960). Ingersoll (1970), however, indicated that the ability to process auditory stimuli more efficiently may vary among subjects. He first pretested subjects for preferred recall. Subjects who displayed preferred auditory recall remembered significantly more auditory messages, whereas subjects who displayed preferred visual recall performed better with visual stimuli. In addition, auditory recall exhibited a recency effect, while visual recall exhibited a primacy effect. Thus, ease of perception of pictorial stimuli appears to be situation-specific and varies with individual differences.

Recognition and Recall: Verbal versus Pictorial. Recognition of pictures is somewhat better than recognition of alphanumerics when both types are judged as new or old (previously presented) (Snodgrass, Wasser, Finkelstein, & Goldberg, 1974). Presenting successive stimuli, experimenters have found visual recognition to be highly accurate even under conditions of "noise" (blurred or sketchy presentations) (Day & Beach, 1950). Magne and Parknas (1963), using either pictorial or alphanumeric slides presented successively, required the subjects to indicate changes in

plant structure (roots, etc.). Subjects who were both taught and tested by the pictorial method performed significantly better than those in the three remaining combinations. Day and Beach's (1950) results were similar, indicating that pictorial stimuli produced significantly better free recall than verbal stimuli. Although there is evidence that learners are able to extract detailed information from pictures, it seems likely that the superiority of pictures is evidenced only for recognition paradigms. Using a recall paradigm, Bergan, Zimmerman, and Ferg (1971) presented numerical, pictorial, and alphanumeric stimuli, variously grouped and displayed on slides, with four to seven slides presented serially. Their fifth-grade subjects did not remember any one of the three types of stimuli significantly better than any other, despite grouping. It appears that the choice of response measure substantially influences the effectiveness of the graphic presentation manipulated.

Delayed Recall. When testing is delayed, the results of some of the above experiments change. For example, Jensen's experiment (1971) using delayed recall testing indicatd that the visual mode was significantly more effective than the auditory mode, with a significant time delay by mode interaction. Similarly, using both children and adults, Ward and Naus (1974) determined that color significantly facilitated retrieval of information that had been initially presented in black and white. Not surprisingly, Lantz (1974) found that subjects who had previously been taught a simple and complex wave discrimination task took significantly longer to produce correct responses, and the response time increased in direct proportion to the delay schedule. The paucity of research employing the delayed recall paradigm prevents the drawing of conclusions about the effectiveness of graphics under these conditions.

There are several hypotheses about the nature of the processes between the encoding and decoding phases (Brunner, 1964; Paivio & Yarmey, 1966). Regardless of the internal process, a methodological problem presents itself. First, pictorial memory is biased by recognition testing. Pictorial memory cannot be effectively tested in the usual response paradigm, because in nonrecognition testing the subject is required to make a verbal response, which may require another coding if indeed the information is stored pictorially. How, then, can a subject make a pictorial response? Drawing almost invariably touches upon distinct abilities, yet drawing is the usual nonverbal dependent measure. On the other hand, most tasks do not require learners to manipulate the pictorial stimuli with which they were instructed; they are more likely to be asked to perform some perceptual or cognitive task. Pictorial tests are not representative of most tasks that people perform, and as such unduly bias the dependent measure; thus, nonpictorial testing more frequently approaches real-life performance requirements.

Summary of Research on Perceptual Efficiency. Although there is evidence that at some basic level visual displays facilitate information processing, the proportion of variance in the learning situation accounted for by such factors as eye fixation and color coding is negligible in terms of predicting the overall effectiveness of visuals for education. Not only

has the perceptual efficiency of graphics been questioned, but several researchers contend that graphics per se do not substantially enhance instruction. Reviewers report that visuals and nonvisuals, or levels of visuals, when compared for instructional effectiveness, result in the "no significant difference syndrome" (Allen, 1971; Briggs, 1968; Dwyer, 1972; McKeachie, 1974; Spangenberg, Riback, & Moon, 1973).

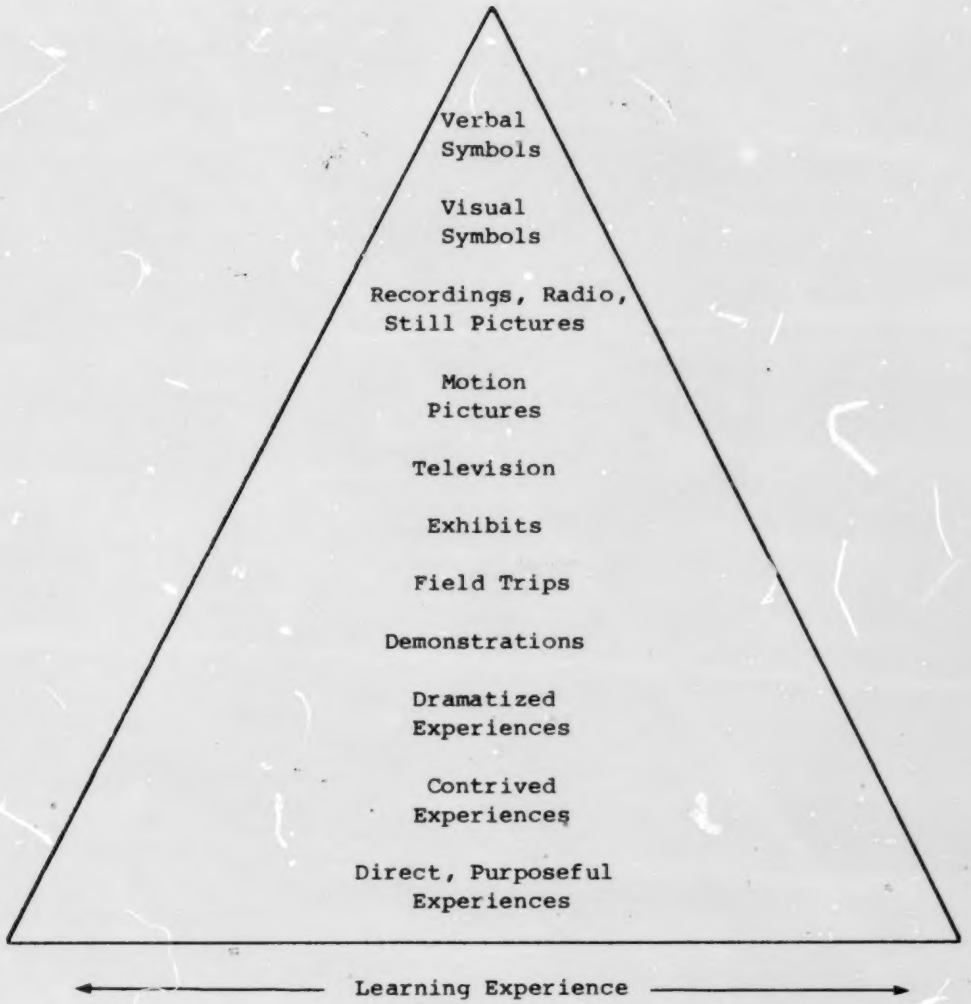
Realism

The emergency training requirements of World War II produced a demand for training simulators and training aids when student/instructor ratios sharply increased, and the priority of equipment assignment was given first to combat and second to training. These conditions significantly affected the direction of subsequent military training, because implicit in this training posture was the belief that the most effective training procedures were those that most concretely approximated the job situation. Longstanding assumptions regarding the educational value of approximating reality (e.g., a picture is worth a thousand words) were given credence and hence perpetuated.

Technological advances brought about the emergence of highly sophisticated audiovisuals, again supported by implicit notions about stimulus fidelity. The emergence of audiovisuals in peacetime training was supported by these underlying theoretical formulations, which collectively became known as the realism theories. Dale's "Cone of Experience" (Figure 1) represents one attempt to define the relationship between the degree of realism and instructional media (Magne & Parknas, 1963).

Because graphics pictorially approximate reality, it was assumed that they were inherently effective instructional tools. It was further assumed that degree of learning transfer was directly proportional to degree of pictorial fidelity.

Dwyer Research. The most systematic exploration of the relationship between graphic level and instructional effectiveness was conducted by Francis Dwyer. A complete review of his work is available in the literature (Dwyer, 1972). Dwyer hypothesized that as the level of pictorial reality increased, so did the student's comprehension of the instructional material. In most of the 11 experiments cited in this section, the paradigm employed by Dwyer was consistent. In seven experiments, course material about the functioning of the human heart was recorded and presented to the subjects by audiotape, while graphic displays were manipulated on slides or other projected visuals. In the remaining four experiments, subjects were presented with printed text materials, with visual displays manipulated on book plates. The dependent measures were four tests: Comprehension, Terminology, Identification, and Drawing. The four tests could be combined to provide a total comprehension score. The reliability of these dependent measures was fairly high; the Kuder-Richardson Formula 20 reported between .85 and .95 in all cases.



The Cone of Experience depicts the belief that there is an increase in learning experience as the instructional presentation goes from highly abstract to highly realistic. From E. Dale in Magne & Parknas, 1963, p. 267.

Figure 1. The Cone of Experience.

In each experiment, visual display was manipulated as a levels variable. A verbal presentation of either alphanumeric or audiotape version alone served as the control. Dwyer expected a simple line drawing presentation to be less effective than a shaded drawing, which in turn would be less effective than the heart model level, and so on, the photographic level being the most effective. In three experiments, Dwyer added the additional variable of color, comparing color and monochrome versions of his visual presentations (Dwyer, 1968a, 1968d, 1968f).

Finding no significant differences supporting the realism hypothesis in his early experiments, Dwyer presented the same material to different age levels (9th-16th graders) and added time to completion and delayed retention as dependent measures (Dwyer, 1967a, 1968d, 1968f). There was some variation in significant results from one dependent measure to another, and Dwyer himself has stated that his experiments failed to support the realism theories.

For the sake of clarity, the Dwyer experiments cited here have been divided according to whether the instructional material was presented by programed text or by projected materials.

Experiments Using Programed Text Materials. The programed text presentation required the student to make a response before continuing. Plates 2-1/2 inches by 3-1/4 inches presented several levels of visual realism. In the nonvisual version, the term being discussed was described alphanumerically on the plate. An additional nonprogramed text version acted as overall control; no plates were used in the overall control.

Table 1 shows that in two of four experiments the black-and-white photograph presentation was more effective than the remaining alternatives. However, it is apparent that the effectiveness of graphic levels varies from subtest to subtest. For example, on the Comprehension and Terminology tests, in no case did students at any level perform better than students who received a nonpictorial version. On the Drawing and Identification tests, however, the photographic and (in one instance) the color model were significantly better than the nonpictorial levels. These results are undoubtedly confounded by Dwyer's use of test stimuli that were a function of presentation stimuli (Dwyer, 1967b, 1968a).

Time Correlation. Dwyer hypothesized that since they provided additional cues, more realistic visual displays might require greater viewing time. Previous experiments had not attended to this notion. Dwyer evaluated this hypothesis through subject report data. In three experiments, Dwyer asked his subjects to keep a record of how long they spent studying the course material (Dwyer, 1967b, 1968a, 1968f). In all three experiments, the results consistently rejected Dwyer's hypothesis. Although the nonprogramed, nonvisual presentation took significantly less time than any other treatment, students spent more time viewing the programed illustration with simple line drawings than any of the more complex visual versions.

Table 1

Four Experiments Manipulating

Visual Display Realism in Programmed Texts

Presentation	Total Score				Identification				Terminology				Comprehension				Drawing			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Alphanumeric	A	C		A	A	A		A						C			A	A		A
Alphanumeric - P. I.		A	A			A				A				A				A	A	
Line - Black & White	A	C	A	A	A	A	A	A	A	C	A	A		C	A	A	A	A	A	B
Line - Color				A				A				A				A				A
Shaded - Black & White	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Shaded - Color				A				A								A				B
Model - Black & White				A				A								A				A
Model - Color				B				B								A				B
Photo - Black & White	B	A	B	A	B	B	A	A	A	A	A	A	A	A	A	A	B	B	B	A
Photo - Color				A				A				A				A				A

A - Presentation manipulated.

B - Scores on this level are significantly higher than the alphanumeric control.

C - Significant on a two week delayed retention test.

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1. Dwyer, 1968e; 2. Dwyer, 1968c; 3. Dwyer, 1968b; 4. Dwyer, 1969.

Experiments Using Projected Materials. The results of Dwyer's experiments using projected materials such as slides, filmstrips, and instructional television are much the same as in his programed text manipulations (Dwyer, 1967a, 1968b, 1968d, 1968e, 1968f, 1969c, 1970b). In general, no presentation was consistently more effective than the alphanumeric presentation (projected alphanumerics) for the Comprehension and Terminology tests. The Drawing test was marked by significantly higher scores, simple line drawings being most effective in six of seven experiments. The Identification test was marked by conflicting results, pictorial presentation being significant in some experiments and not in others.

In two experiments, Dwyer took delayed retention measures (Dwyer, 1968d, 1968f). In most cases, scores in the alphanumeric condition were significantly improved, and any initial differences between alphanumeric and visual presentations were eliminated. In one exception--Terminology retention scores were higher for subjects in the black-and-white heart model presentations and in both photographic presentations. These results are somewhat more readily interpreted if one excludes the terminology experimental results. Delayed retention scores then show significance for the alphanumeric presentation only. When compared to delayed retention scores using programed texts, a discrepancy appears: the simple line drawing level shows significant improvement with delayed retention. A possible explanation for this inconsistency is that these results are due to an interaction between the disseminating media (in this case, text vs. projected visuals) and the level of visual presentation. For example, the programed text undoubtedly allowed for more individualized instruction because it was self-paced, whereas the slide presentation was group administered. This concept is discussed in detail in the section on visuals and media.

Related Research. Several researchers have manipulated attributes of visual displays according to the realism continuum (Cooper & Gaeth, 1967; Wheelbarger, 1970; Moore & Sasse, 1971). Moore and Sasse (1971) concluded that developmental factors influence the student's ability to learn from pictures. When they manipulated the type (drawing, photograph, painting) and size (half-screen, quarter-screen, full screen) of projected slides, they found that the effectiveness of display characteristics varied with age and grade level of their subjects.

Wheelbarger (1970), whose experiment closely followed the Dwyer paradigm, found that his sixth-grade subjects had difficulty with the material when visuals were excluded. Thus, research using different age groups suggests that the instructional effectiveness of graphics varies with cognitive skills. Wheelbarger divided his subjects according to scores on the Lorge-Thorndike word norms (94 and below; 95-110; 111 and above) and presented them with one of several experimental slide conditions: alphanumeric, shaded drawings, and photographs, the latter two in both color and monochrome versions. No significant differences were reported on the operations or recall test; however, students who scored in the high intelligence quotient (IQ) range and who had been assigned to the verbal condition scored significantly lower than their counterparts in

the other experimental conditions (Wheelbarger, 1970). In contrast, Hagaman (1970) reported no significant differences between verbal and pictorial groups for subjects of varying IQ, although the subjects in the higher IQ range scored significantly better overall.

Although no significant difference between simple line drawings and color photographs was reported in learning a task that required subjects to pair words and pictures, Wicker (1970) reported that the strategy (mediation or rote) used by each subject did affect performance. Mediation was more likely to reduce errors in the photographic group. Again, it appears that intellectual and educational factors influence the effectiveness of visual displays.

Results of three experiments directly conflict with the realism theories--with the cone of experience in particular. Following the belief that realism enhances learning, Gropper (1968) compared the effectiveness of hands-on performance versus a visual instructional program. The task, which required the subject to assemble a three-pole motor, was performed significantly better by subjects assigned to the hands-on group. However, Gropper stated that this superiority was more apparent in the early stages of testing and suggests that it is the result of motor practice rather than of superior learning of the task.

In contrast, Austin (1972) found that a manipulative instruction group did worse than a pictorial presentation group. However, since the lesson content was statistics rather than a perceptual-motor task (having subjects flip coins to illustrate probability theory), the results may not be meaningful in the traditional sense of manipulation. Finally, Laner (1955) tested the effectiveness of motion pictures versus still pictures derived from the motion pictures for teaching a perceptual-motor skill for which he believed the subject needed to understand the functional interrelationships of parts in motion. Three immediate tests were administered: draw a rough sketch, answer 18 oral questions, and assemble the trigger mechanism. No significant differences were found attributable to presentation mode.

Realism and Color. The dimension of color has been of particular interest to researchers of graphic presentation, in part because color enhances realism. The Dwyer paradigm included the addition of color to each visual level in three of his experiments (Dwyer, 1967b, 1968d, 1968f). Dwyer stated that the addition of color did not result in an overall positive effect (Dwyer, 1971); color did, however, seem to have a somewhat consistent effect in Dwyer's experiments. For example, for programed instruction, the shaded drawing was not as effective as some visual presentations. For projected materials, however, shaded drawings could be enhanced by the addition of color. The color heart model in the programed presentation was effective, whereas the black and white was not (for the Identification and Drawing tests). It is possible, then, that tasks that require a more visual response may, at some levels, be enhanced by the addition of color.

Results of other experiments manipulating color in the realism continuum are very similar (Hagaman, 1970; McCoy, 1962; Vandermeer, 1954; Wheelbarger, 1970; Wicker, 1970). The Wheelbarger and Wicker experiments already described found no significant difference attributable to the use of color. Hagaman instructed all of his students with the same materials, but he varied the level of realism and use of color in his test stimuli. He presented his third-grade subjects with 17 pictures and object names: color picture, black-and-white picture, monochrome line drawing, or object name alone. Results indicated no significant differences related to response stimuli. Additional analysis revealed, however, that boys responded significantly better to tests with color pictorial stimuli (Hagaman, 1970).

McCoy hypothesized that an audience would rate color film presentations as more real than black-and-white presentations of the same (documentary) material. Results indicated the reverse; the audience more frequently judged the monochrome version as realistic (McCoy, 1962). This result is probably due to more frequent exposure to monochrome documentaries.

In an experiment designed to tap a visual and social class interaction, Morgan (1971) presented either color or black-and-white illustrations in texts on tractor repair and mower maintenance. Subjects were chosen from ninth graders enrolled in the South Carolina public school agriculture classes and, by quota sampling, were assigned to experimental conditions according to race and economic status. Colored illustrations did not have a significant effect on either immediate or delayed retention (6 weeks). Upper-class white subjects, however, did somewhat better on the color presentation.

Summary of Research on Realism. The hypothesis that highly realistic graphic presentations teach material more effectively than do less realistic presentations has much face validity. However, the hypothesis is not supported by the literature. Though experimentation in this area is marked by lack of replication, it appears that if realistic visuals significantly enhance learning, this result should be reflected in the literature--yet it is not. There is evidence, however, that several factors may influence the effectiveness of visual display. As seen in the previous studies, the effectiveness of visuals has varied with the dependent measure employed. There is an indication that some subject matter is more conducive to visual presentations than others. IQ or mnemonic devices, or possibly other subject characteristics (e.g., age), may interact with types of visuals. In addition, color, which is often thought to increase realism, has limited applicability. Rather than being intrinsically effective, color appears to enhance selective visuals, particularly in those experiments which use visuals as part of the response requirement. Generally, then, use of visuals should be carefully weighed against task, subject matter, and student characteristics.

Learner Preference and Motivation

The opinion that visuals significantly affect learning because they create a pleasing learning situation, are positively motivating, etc., is prevalent in education today. Research on learner preference for certain instructional stimuli is seen as a valuable adjunct to any instructional development program; newer technology studies are often accompanied by post hoc measures of a learner's attitudes toward the instructional situation (Dwyer, 1967d; Siegel, 1973).

Some efforts to experimentally measure preference as arousal have also been made; the most notable being the Hess research (1965) on pupillary response. Media preferences measured by physiological data such as pulse have also been attempted (Bruha, 1970; Silber, 1969). These researchers found some reaction to film as a media, but more frequently they found reactions to film content. More important, Bruha found a discrepancy between teacher and student preferences. There are, however, little data to support the notion that a subject's preference for a particular kind of instructional stimulus necessarily affects performance.

Subject preferences do not necessarily enhance the teaching effectiveness of particular modes, but there is evidence that preference does significantly reduce attrition (Wali, 1970). In a study of adult learner preferences in Iran, Wali found that both teacher choice of mode and student preferences for mode reduced the dropout rate. Thus, in the long run, learner preference may affect learning.

Children's Preferences. A review of the literature of visual preference has been made by Spaulding (1955), who reported the following: Children prefer books with brilliant color illustrations; these illustrations should cover at least half a page, ideally a whole page; and realism of the illustration takes precedence over color, as children prefer realistic black-and-white to colorful nonrealistic presentations. Children's visual preferences are reported to change as they develop, according to Spaulding's review. Younger children often prefer specific colors, such as red. They also prefer simple line drawings, whereas by fifth grade, most children prefer more complex illustrations (such as photographs) over simple ones (85% vs. 15%). Younger children prefer that the content of illustrations (and thus the stories they accompany) be about familiar things, while older children prefer the exotic. For example, younger children prefer stories about domestic animals, and older children prefer stories about wild animals.

Adult Preferences. Adult illustration preferences are somewhat different from children's, with some variability owing to sex differences. Overall, women prefer illustrations containing more classical themes, and men prefer sports and do not mind mildly gory scenes. Spaulding (1955) reported, however, that both sexes lacked interest in photographs with new or unfamiliar materials (e.g., ambiguous) or those "that were vague as to content or action" (p. 39).

Attention and Preference. The possibility that content is a strong factor in determining preference is suggested by Kaplan, Kaplan, and Wendt (1972). They found that, contrary to popular opinion, preference for illustrations could not be explained on a simplicity-complexity dimension. In their experiment, content (pastoral vs. urban) had the greatest effect, some scenes being preferred to others. Sloan (1972) also found that content significantly affected preference, but in her study of varying socioeconomic levels, style of presentation and sex of subject also significantly interacted. Overall, males preferred the more realistic presentations to line drawings, and females showed more varied responses.

Increasing the size of photographs in newspapers has also been found to increase attention to a certain pictorial; when a picture was large, subjects read the accompanying text more often. In the same way, color increased attention to particular stimuli, and color pictures elicited increased reading of material. But alphanumeric displays such as headlines produced an interactive effect between the meaning of the headline and size. The headline had to be phrased so as to complete a thought before subjects attended to the subsequent text (Spaulding, 1955).

Visual Preference and Performance. Overall then, there is some evidence to indicate that preferences for visual materials are a function of several individual characteristics, including age and sex. However, the proposition that these factors significantly affect learning from materials containing the stimuli preferred by a particular group, and indeed that these preferences will act as screening devices, is not supported by the literature. For example, Laughery and Fell (1969) found that despite learner preference for the visual mode, subjects in a memory-span task performed better on the auditory than on the visual presentation of material.

There is some evidence that preferred visual stimuli may be counterproductive in some instructional situations. For example, Halbert (cited by Spaulding, 1955) found that illustrated versions of a text elicited more ideas from children, but that these ideas were more often than not directed away from the central theme of the material. In essence, the illustrated text created more distractions than did the nonillustrated version. She concluded that if the task is to teach about a particular concept, illustrations may be counterproductive.

Color and Preference. Perhaps the most widely accepted belief about the effectiveness of any one stimuli, or attribute of an illustration, is that a color version of an illustration will more effectively communicate an idea than a monochrome version of the same material. The assumption for this belief is that color is pleasant and thus a very strong motivator (Dwyer, 1971; Laner, 1955). There is little doubt that most subjects prefer color illustrations (Vandermeer, 1954), but as with overall preference for visuals, there is little evidence that this preference significantly affects performance when color and monochrome presentations are compared. For example, Vandermeer showed five black-and-white films to 9th and 10th graders. Subject matter included maps, rivers, snakes, sulfur, etc.

Dependent measures were both verbal (sentence completion, multiple choice) and nonverbal (pictures, graphs). The results of tests given both immediately after the screening of the material and after a 6-week delay showed no significant difference due to the addition of color. Replication of the same paradigm for ninth graders with no delayed retention tests had the same results, although subjects in this experiment reported that they preferred color presentations, and subject matter did positively interact with this preference, with no sex differences.

In an attempt to measure the positive attitude toward the use of color, Wright and Gardner (1960) had men (of whom two-thirds were blue-collar workers) rate three versions of four three-color pictures, using Osgood's Semantic Differential (Osgood et al., 1957). The author hypothesized that color was an additive type of stimuli and that preference for color would show up as a response evoked in an additive manner. They found that in some cases subjects responded to color independently of pictorial content, but in others there was a strong color and content interaction.

Summary of Research on Learner Preference. The literature indicates that visual preferences do exist, perhaps correlated with other factors such as age, sex, and socioeconomic position. However, there is little evidence to support the notion that preferences for particular visual stimuli affect performance. This latter statement does not necessarily contradict the laws of motivation and learning. It may very well be that subject preference measures include more factors than were initially apparent. For example, asking subjects to describe their preferred instructional modes may elicit either "Which do I like the best?" or "By which do I learn best?" Farr's research (1970) addresses this issue. Subjects were assigned to instructional methods according to which method they thought they would learn best by--not identical to which they preferred. Subjects performed significantly better when using the method of their choice. Thus it is suggested that attitudes about learning may be implicit in the preference measure chosen.

There is little research on preference-prediction in visuals. Visual likes and dislikes are usually measured post hoc (Dwyer, 1972) rather than by assigning subjects on the basis of their preferences. Schiff (1970) demonstrated that experimentally manipulating preference and content in the visual situation may be awkward. Believing that content would affect evaluation of a film, in particular the estimate of the duration of the film (the dull films being judged as longer), Schiff measured like-dislike and perceived duration of several films. The results were not significant; subjects' estimates of film duration were highly inaccurate in all phases of the experiment. This result suggests that subject report of effectiveness of some preference factors may be highly unreliable.

Preference does not appear to be an important variable in instruction per se. Furthermore, little research has addressed the separate components of preference. Until an organized body of literature supporting preference as a factor in visual learning is developed, preference for visuals does not appear to justify their use.

Multiple Sensory Input

The belief that graphics can increase learning because they add additional sensory input is present in educational technology folklore today. Several researchers have addressed the issue of simultaneous presentation of multiple media (Cody, 1962; Devoe, 1965; Olsen, 1969). Advocates theorize that if one medium will suffice, then two or three must be better; or they espouse the shotgun approach--if an effective method is not known, try everything. These theories have their basis in the hypothesis that simultaneous presentations unburden overloaded sensory channels. Two types of research have been described: experiments manipulating stimuli on a more basic sensory encoding or perceptual level (as presented in the previous section on perceptual efficiency), and those evaluating multimedia in the instructional environment.

The basic research findings have been described in a review by Devoe (1965), who reports a growing body of literature indicating that "human perception is essentially a one channel system" (p. 6). There is some evidence that simultaneous transmissions of simple material can be processed effectively (Devoe, 1965; Mowbray, 1954; Sumby & Pollack, 1954). Usually, however, simultaneous stimuli (such as auditory and visual signals) are handled alternately (Broadbent, 1956; Devoe, 1965; Fitts, 1971; Kristofferson, 1965). Though the results of the research in this area are highly complex, in most studies simultaneous transmission did not necessarily increase the effective processing of the stimuli; in fact, in some experiments subjects performed worse than chance (Mowbray, 1954). Thus it does not appear that, at a basic level, simultaneous transmissions necessarily unburden overloaded channels.

Within the instructional environment, the results of experiments testing the effectiveness of simultaneous media presentations have varied. Despite these findings, simultaneous presentations of every conceivable kind of audiovisual have been popular gimmicks, based on the belief that they lead to more efficient storage. In a study by Olsen (1969), a medical self-help course was taught by one of several presentations using audiotape and one other media, such as slides or movies. Scores on tests designed to measure the traditional verbal knowledge aspects were not significantly different. However, performance of the first-aid tasks showed a significant gain in performance scores as more sophisticated media were added. In an experiment by Cody (1962), combinations of reading, listening, and note-taking were investigated. No interference was indicated as a result of the extra techniques; however, the most effective method was silent reading.

Though attitudes toward simultaneous presentations probably do not have a more influential effect in this area than they do in other educational contexts, there is evidence that attrition rates may be drastically reduced by the use of multimedia packages. In one case, attrition dropped from 40% to 8% (Hall, 1971).

In summary, the basic premise that simultaneous presentations of visual stimuli are able to unburden overloaded channels has not yet been substantiated. Moreover, the generalizability of this premise to the instructional environment does not appear to be warranted.

Visuals and Instructional Media

In the late 1950's and early 1960's, several movements toward the use of some audiovisual technology began on a nationwide level. For example, language laboratories became an adjunct to language learning, and closed-circuit TV appeared on university campuses and in many high schools. Overall, the movement was toward more sophisticated audiovisuals; audiovisuals were transformed from the notion of teaching aids to actual teaching devices. Overhead transparencies, filmstrips, films, etc., were quickly replaced by television language laboratories, sophisticated simultaneous training devices (Stoltz, 1971), and computer-assisted instructional systems.

As technology advanced by leaps and bounds, however, the instructional course ware for these systems progressed slowly. Material for training devices in particular could be easily updated to keep up with equipment changes. Course material for teaching troubleshooting on a piece of missile tracking equipment illustrates this point. Some systems and system approaches were abandoned early, whereas other concepts became popular. Instructional television falls among the latter; it is among the few systems on which much evaluative research has been done.

Several studies have examined alternative instructional media. Although there is no specific theory relating visuals and media, media studies provide an indirect means of evaluating instructional graphics, as certain media readily lend themselves to graphic depiction of material. Indeed, in some instances the primary rationale for selecting a particular medium is the capability of that medium to generate sophisticated graphics. Instructional television (ITV) is a prime example of this latter category.

Television. Visual displays are intrinsic to an ITV approach. It was believed that the student could benefit from both an organized lesson and the accompanying displays, including closeups and detail of the actual laboratory setting, without leaving his seat. Programs were less expensive to produce, because many students could be taught by one instructor on a closed-circuit line. Research looking at some of the factors influencing the effectiveness of television for instruction is plentiful, yet the results still are somewhat inconclusive. There is little

doubt that television can be a very effective instructor (Anderson, 1972; Bart, 1971; Dwyer, 1968f; Jackson, 1955). Bart described some variability in effectiveness, due to socioeconomic class, in his experiment with third-grade students. Dwyer maintained that the notion of the ability of television to accurately simulate the laboratory setting (say, a physics experiment), show detail, etc., is an oversimplification of the design process, as illustrated by his visual realism experiments (Dwyer, 1972). He stated that an increase in the amount of information contained does not necessitate an increase in information conveyed to the learner. Furthermore, Dwyer asserted that most televised instruction programs are the result of the producer's creativity and not systematic instructional strategies.

There is evidence, however, that television can be systematically evaluated by properly designed research. For example, both Barrington (1971) and Jackson (1955) designed programs using effectiveness feedback. In Barrington's experiment, two variations of the same material were presented, the first being taped instruction (TI) of a regular classroom lecture, and the second an edited version of the first, using animation and cutting out extra noise and background. Subjects, matched for ability and sex, were assigned to one of the treatments. Results indicated the edited program was more effective. However, there were no significant ability or treatment interactions (Barrington, 1971).

The Jackson research concentrated on determining principles that would aid the instructor in designing effective visuals for instructional television presentations. Staff members from the Human Engineering Division of the Special Device Center, U.S. Navy, rated 105 existing programs for visibility (i.e., clarity of the televised image) on a 14-item Likert scale (reliability = .85 - .96). The ratings fell into a normal curve, with the first quartile very good and the fourth quartile poor. Next, a display containing all the positively rated features was constructed. The other displays were then reconstructed to include portions of the properties derived. Ratings on the revised displays increased significantly. Finally, displays were rated by the experimenters according to the derived principles, and predictions about their ratings were made. Predicted ratings correlated significantly with actual ratings ($r = .90$). In all, 31 principles were delineated on the assumption that high display quality facilitated learning.

Color. Experiments testing the effectiveness of televised instruction included manipulating color versus black-and-white presentations (Booth, 1971; Kanner & Rosenstein, 1960). Results have mimicked color studies previously described, with no significant differences attributable to the addition of color but some significant color-content interactions.

For example, the Kanner and Rosenstein paradigm selected 11 lessons from three Army Military Occupational Specialties (MOS). They presented black-and-white or color versions of each lesson; each lesson was given three times and followed by immediate testing. Some of the test items, called "color items," either had color as an integral part of the phrasing of the question or the subject was required to have specific color knowledge (for example, one question pertained to a certain colored resistor and its value in ohms). Only one lesson, Range Tracking, resulted in higher scores attributable to the addition of color. The decision to develop lesson materials in black and white followed. The experimenters felt that the results were due to a color-content interaction, or the small percentage of color material shown to be significantly more effective (11%) did not warrant the overall use of color.

Booth (1971) explored the affective value of color. In response to the idea that color may elicit unwanted emotional arousal, second-, third-, fourth-, and sixth-grade students of varying socioeconomic backgrounds were presented with either color or monochrome presentations. Prior years of viewing color television did not constitute a significant factor. However, a significant developmental trend was noted. The second-grade students tended to internalize attitudes portrayed in black and white more than those in the color version, and the trend for sixth-grade students was exactly the reverse. Fourth-grade children were described as being in a transition period.

Visual versus Auditory Media. Overall, visuals have been reviewed across modalities as having some positive, yet variable, results. Day and Beach (1950) report in their review that for paired associate learning, difficult material is better presented visually, and simpler material is better presented auditorily. In addition, the younger children did not benefit from visuals as did the older children or the more intelligent children.

Visuals versus auditory modes, particularly the auditory presentation found in TI, have been compared in several experiments (Cooper & Gaeth, 1967; Dworkin & Holden, 1959; Edgerton, 1957; Hanneman, 1968). Some of the variability in results has been attributed to content-mode interactions, as in a study by Edgerton (1957) wherein learners gained more from the use of pictures (slides) on some materials than on others.

A developmental effect included in the content-mode interaction was noted by Cooper and Gaeth (1967), who presented material to students in grades 4, 5, 6, 10, and 12 by visual or auditory modes. Supplementing the Day and Beach observations cited above, these authors suggest that the ability to gain from pictures peaks somewhere in late childhood, and that by grade 12 students function better in a verbal (text and aural) mode than in a visual mode. This proposition is also suggested by Collins (1971), who found that second graders perform equally well on several kinds of visual-alphanumeric presentations teaching spelling. Collins used both an achievement test and a 1-week delayed retention test.

In the Dworkin and Holden experiment (1959), filmstrip and audiotape presentations versus TI-designed by the same instructor were compared for their effectiveness in teaching atom bonding material to engineering graduate students matched for education and previous course grades. No significant difference was noted in course achievement. However, questionnaires did yield significant attitude trends. The audiotape was criticized as being too fast (135 words per minute (wpm) compared to an average rate of speech of 120 wpm). In addition, 40% of the students in the experimental group said they would have liked a chance to ask questions. However, student opinions did not correlate with any trend in achievement.

Motion as an Instructional Cue. A few studies have directly compared alternative audiovisual media. For example, when slides or filmstrip methods are compared to moving film presentations, the actual movement of the stimuli describes the major difference. Sometimes the richness of detail, particularly the detail of the simulated environment, has been described as a contrasting factor (Devoe, 1965). Television and videotape have had reported effectiveness in training by reproducing behaviors that the subject can later alter, such as gymnastics (James, 1971). In an educational context, videotape was found to aid practice teachers in their teaching behaviors. Students in the experimental videotape group received significantly higher ratings in their practice teaching than did the control group who had TI practice sessions rather than videotape feedback (Jensen & Young, 1972).

Absence of background noise is also described as a factor contrasting television and TI (Sprague, 1955), and there is some evidence that background noise is a negative factor; but overall, motion is usually described as the important addition (Dwyer, 1969; Houser, Houser, & Van Mondfrans, 1970; Laner, 1954). The addition of motion addresses either or both of two specific strategies the instructor is using. First, there is the attention-motivation value of motion; researchers have looked at two aspects here. Dwyer found that motion (operationally defined as pointing to the important area of the heart in videotape presentation), did not significantly affect performance (Dwyer, 1969). Sprague (1955) compared the effectiveness of four types of visual presentation of information about machines to sixth- and seventh-grade boys and girls. Magazine clippings, commercial film, and combinations of the two comprised the experimental conditions, and magazine clippings presented as a filmstrip comprised a fourth condition. No significant difference on subsequent tests was attributed to mode, except that subjects having higher ability did better on the commercially produced film than did those with lower ability. On the other hand, Gettinger (1971) did find significant differences between videotape and still-picture presentations and subject (fifth and sixth graders) performance in identifying motion.

The second strategy for using motion is to facilitate later perceptual-motor behavior. The subject is thought to be better able to understand the interrelated movements in a performance task by vicariously experiencing the task through film. Laner (1954) tested that idea by presenting a filmstrip or film of how to repair a broken window sash. The instruction included how to disassemble, repair, and reassemble the materials. The filmstrip presentation was made from 51 still blowups from the film. It was believed that these frames did not include motion and overall were much less sophisticated than the film presentation. The dependent measure was a 23-item performance test in which the subject was rated on his ability to make the repairs; time to completion was not measured. Results indicated no significant differences attributable to method used, although previous carpentry experience did prove to be significant.

Last, a comparison was made between alphanumeric and aural presentations of descriptive captions accompanying a movie demonstrating to agricultural students methods for grading cereal grains (Hanneman, 1968). Both identification and performance measures were taken. Students in the visual group (alphanumeric) did significantly better on the identification tests than did students in the aural group. However, no performance differences were found.

Media and Instructional Strategy. The idea that one medium is intrinsically more effective than any of the other media is simplistic. The specific factors that enhance learning in the instructional situation are no longer restricted to the context of particular equipment, but rather are considered within the total instructional system, which includes the instructional strategy. The strategy is usually built into the system, and flexibility for changing this strategy varies from system to system.

Many researchers have written that direct comparison of one system with another is not a valid approach, since the basic strategies are markedly different in many cases. For example, CAI programs typically employ reinforcement, self-pacing, individualized sequencing, etc., whereas instructional television provides a more directive type of teaching and is oriented to group rather than individualized instruction. Texts may differ also; in addition to their visual layouts, the decision to present examples and then generate rules or vice versa is implicit in the writing of the material.

In contrast, decisions about instructional strategy may also be made independently of the instructional system. In relation to learning from visuals, several experiments illustrate that certain instructional techniques, such as the use of advance organizers, post-organizers, and interrogative or imperative captions, can be effective (Ausubel, 1960; Bertou, Clasen, & Lambert, 1972; Butts, 1956; Dwyer, 1970; Neu, 1951).

For slide presentations, questions as captions do not appear to be as effective as declarative or imperative captions (Butts, 1956; Dwyer, 1970a). In Butts' experiment, both immediate testing and 2-week delayed tests showed imperative and declarative captions to be more effective than questions as captions, except in the case of one content area.

For written text, there is evidence that advance organizers facilitate learning (Ausubel, 1960), and television presentations have shown a positive effect for interspersed questions followed by a short pause (Bertou et al., 1972). Other attention-getting devices were manipulated by Neu (1951). In his paradigm, both relevant and irrelevant material were used to direct the subject's attention to particular procedures. The visual attention-getting devices were of questionable relevancy; for example, when demonstrating that a metal ruler should be oiled, an oil can appeared as the word "oil" was spoken. Nonrelevant stimuli included pretty girls and cows' tails. The results did not indicate that Neu's extra visual cues aided learning; in fact, scores on both a 104-item multiple-choice test (KR_{20} = .94) and a 77-item recall test indicated that irrelevant devices were distractors in that they lowered scores. In summary, since visuals are associated with the visual aids or advanced system described previously, their value is difficult to assess. Research on instructional strategy indicates that some methods of presenting the learner with material are more effective than others. The success of some media may be due to their amenability to effectively use instructional principles rather than to the use of visuals.

Programing material for a computerized presentation, televised presentation, or film requires more planning than do most TI presentations. This attention to detail and organization probably accounts for a good deal of the effectiveness of the medium. If system engineering principles were applied to TI or to less-sophisticated media such as slide projection, the effectiveness of both would probably be increased (Radan & Zuckowsky, 1969, 1970; U.S. Civil Service Commission, 1971). Research on system comparisons must be reviewed carefully. As Gropper (1968) stated, most experimentation of this nature is invalid, since it does not compare two equally well-constructed methods.

Although it is valuable to examine experimentation on instructional media, the results of such experimentation are confounded by a number of factors, including the instructional strategy, the subject matter, the physical demands of the hardware, and the system goals.

Individual Differences

As has been discussed previously, secondary results from a number of experiments have suggested that graphic effectiveness is in part a function of learner characteristics. The examination of individual differences has received considerable impetus with the introduction of aptitude by treatment interaction (ATI) methodology. As early as 1957, the application of ATI methodology was suggested for military training (Edgerton,

1957); however, development of education and training devices has been disappointingly slow. The following discussion deals briefly with the characteristics that appear most relevant to educational graphics research.

Educators maintain that individual differences, especially in the traditional instruction context, hold back some students and allow others to excel, thereby acting both to the advantage and disadvantage of instruction. It was hoped that instruction could be designed with these differences in mind. But as Tallmadge and Shearer (1971) indicated, the process of identifying the most relevant individual differences is much more difficult than it first appeared to be. Educators have persisted in studying the question, maintaining that normative data collection and program development geared toward the average student (who does not exist) overlooks the individual and suits no one (Snow & Salomon, 1968). The goal of ATI methodology is, then, to elucidate the most powerful effects and to develop adequate screening devices for assigning subjects on the basis of the important differences.

Programed instruction (PI) is a type of individualized program. It does not necessarily take into account known individual differences, except the need for self-pacing. Many studies relating specific cognitive and personality variables to either media or instructional strategies have been conducted. The resulting significant interactions are almost as numerous as the studies themselves. For example, research indicates that some subjects will benefit more from visual presentations than will other subjects (Bush, Gress, Smith, & McBride, 1965; Levin, Divine-Hawkins, Kerst, & Guttman, 1974; Tallmadge & Shearer, 1971). There is also evidence that visual effectiveness in education is dependent upon cultural and physical limitations (Fitzpatrick & Hansen, 1973; Kilbride, Robbins, & Freeman, 1968; Miller, 1973).

ATI studies have ranged from those seeking individual differences related to broad educational techniques, such as mode interactions (Goldberg, 1972), to those concentrating more on the subject-generated characteristics of the interaction, such as personality. Learner types have been proposed (Britt, 1971; Haskell, 1971). Britt's study was correlational, using 59,000 subjects ranging in age from 9 to 19 years plus a large computer analysis of millions of correlation coefficients from the data. From these data, three learner types were deduced. Haskell's procedure was more conventional. He determined that learner type could be related to adjectives operationally defined by scores on tests (e.g., Friendliness on the Edward's Personal Preference Schedule).

Other types of ATI studies have emphasized the particular problems arising from a specific learning environment; for example, O'Neil's anxiety studies in the case of CAI (O'Neil, 1972; O'Neil, Speilberger, & Hansen, 1969). Also, since visuals have been counterproductive in some experiments and have been criticized as distractors, some studies have tested the distractability of visuals. Bee (1966) did so in a non-CAI context and found significant sex differences--females were more vulnerable to distraction than males. On the other hand, Tobias (1973) did

not find distractability to be a significant factor in the CAI context. In effect, although ATI methodology appears promising, those characteristics of particular importance to the use of instructional graphics have not yet been clearly identified.

Overview

The literature reviewed does not readily lead to a summary of the effectiveness of pictorial presentations in education and training. The experimental results show no linear trends that clearly determine how the instructional program developer (or teacher) should select visuals, or in which situations they should be used. The commonsense approach is restricted to face validity, as research does not definitely support the use of pictorials according to any consistent criteria. However, it has been substantiated that pictorials can and do, in specific instances, have an effect on some instructional programs.

Significant differences appear in a variety of studies, although many of these differences are too small to have practical application. Some instructional programs are enhanced by the use of pictorials, as attested by several of the studies cited. In effect, the variable results obtained from experimentation (hence the lack of generalizability) suggest that while pictures do aid some kinds of learning, the specific conditions are not accurately known. Nonetheless, three major factors that must be accounted for do emerge: subject matter, task requirements, and learner population characteristics.

CAI AND GRAPHICS

As the literature search progressed, it became clear that reported research directed toward evaluating the instructional effectiveness of graphics in a CAI context, particularly interactive graphics, was almost nonexistent. This section therefore discussed overall evaluations of CAI and related techniques, in order to identify characteristics inherent in CAI relevant to determining the contribution of graphics per se.

Computer-assisted instruction, computer-based instruction, or computer-managed instruction all refer to new educational technology media that have the potential of presenting the student with material conditional upon his responses. This interactive characteristic is unique to CAI. CAI critics often rebuke CAI presentations as expensive, automatic page-turners for otherwise programed instruction. This judgment may be partly correct, but the word "automatic" is not necessarily derogatory, because it is this feature that permits large amounts of instructional material to be presented to many students in a single session. Moreover, interactive graphics is a potential found only in the CAI approach. No textual presentation can provide graphic feedback conditional upon the student's response.

In the past decade, many content areas have been presented via CAI. Although rigorously defined material such as mathematics and grammar has been emphasized, several major conferences have been devoted to the development of computer curricula (Proceedings of the 2nd, 3rd, and 4th Conference on Computers in the Undergraduate Curricula, 1971, 1972, 1973). The literature cited here includes several of these content areas, notably physics, management, and math (Bennett, Bignell, & Bradley, 1972; Bork, 1971a, 1971b, 1972, 1973a, 1973b, 1974a, 1974b; Hammond, 1971; Hertlein, 1972; Martin, 1973; Peters, 1969; Shostack & Eddy, 1971; Wylen & Schwartz, 1973).

The amount of research evaluating CAI is not as substantial as one might expect. Educators apparently feel that CAI is a future reality; consequently, CAI research appears to have been more development-oriented than evaluative.

In a state-of-the-art paper, Jerman (1972) cites several ways in which a CAI approach can facilitate education today.

> These assumptions that lead us to place as much hope as we do in CAI are the following: (1) man is capable of learning more than he is being asked to learn; (2) there are a manageable number of different approaches to instruction that can be tailored to individual differences among students; (3) through careful diagnosis insight can be gained on how one ought to go about individualizing instruction; (4) reinforcement and feedback should be immediate during instruction; (5) in each instance the quality of education that a person receives ought to be the highest possible. (Ianni in Jerman, 1972, p. 466)

It becomes evident, then, that the CAI approach allows not only for education and training but also for experimental research. The majority of experimental research seems to be geared, here, toward learning theory manipulations rather than improvement of the CAI product.

In his review, Atkinson (1968) specifies three kinds of CAI systems: the drill and practice approach, which acts as an adjunct to TI; the dialogue system, in which the student has complete control over sequence of learning events and natural language responses to an unrestricted mode; and the tutorial program which may be seen as an alternative to TI. This discussion focuses on the latter system.

In his study of the effectiveness of CAI, Atkinson used first graders who participated in a CAI reading program. The control group took a CAI math course. Atkinson's approach to his data analysis was somewhat different from that of other CAI studies. Rather than measuring the difference in rate of responding (which he reported to be small), he took frequency data, measuring the total number of responses made. The difference between the amount of material covered by the slowest and fastest child

was 4,000 responses in the 6-month experimental period. Atkinson concluded that CAI does have the potential to meet individual needs. The educational effectiveness of CAI also showed very positive results. Gain scores on the California Achievement Test and the Hartley Reading Test showed that the experimental group's scores were significantly higher in all subtests (such as Vocabulary and Pronunciation) except Comprehension. Atkinson's results suggest that in order to determine the beneficial effects of CAI, one cannot rely upon the traditional verbal-oriented dependent measures.

The literature seldom disputes the instructional technologists' claim that CAI is an effective instructional tool; several reviewers have presented evidence that CAI is no less effective than TI (Anderson, 1967; Gagne & Rohwer, 1969). But objections about some aspects of the instructional situation have been raised. Foremost of these objections is the conjecture that the CAI situation is highly anxiety producing, and that feedback in particular can have a detrimental effect on an anxious subject. To test this hypothesis, O'Neil et al. (1969) took both trait anxiety (A-trait) measured by the State Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, & Lushene, 1969) and state anxiety (A-state) measured by systolic pressure. Variation in subject performance was related to A-state and difficulty of material. Hansen and O'Neil (1970) reported similar findings. In a later experiment, rather than assuming the CAI situation to be inherently anxiety-producing (stressful), O'Neil (1972) presented subjects with negative feedback in his stress condition. High A-state subjects performed worse than low A-state subjects, a result somewhat inconsistent with drive theory. A significant periods effect was also reported, in which errors decreased temporarily across lessons.

Tobias (1973) studied the effects of interrupting the subject during the CAI presentation, calling this factor distractability. Results indicated no learning decrease, but an increase in time to completion. The method of presentation was also manipulated by having the subject respond overtly or by having the subject read. The overt response was correlated with better performance; however, it as also correlated with state anxiety, which was measured at four separate times in the presentation.

Results of several experiments, then, do not support the hypothesis that CAI is an anxiety-producing situation that will have negative effects on performance or personality. In addition, correlation between A-trait measures (as screening devices) and A-state measures is somewhat low, $r = .4 - .7$ (Spielberger, Gorsuch, & Lushene, 1969).

Graphic Studies

CAI evaluation has been more often limited to the development of lesson content for specific subject matter than concern with experimental comparisons between alternative techniques. For example, much effort has been made to develop CAI courseware for physics (Bardwell, 1971; Bennett, Bignell, & Bradley, 1972; Bork, 1971a, 1971b, 1972, 1973a, 1973b, 1974a, 1974b; Martin, 1973). These programs have sophisticated presentations of

materials, including drill, practice, and tutorial lessons; most include graphics. Developers of this material have strongly advocated the development of pictorial material for CAI (Bork, 1974a). Some experimenters (and students) have gone to great lengths to generate graphics, even using pen plotters (Hertlein, 1972; Hurle, 1970; Papert and Solomon, 1972). To date, then, the move to include pictorials has been hand-in-hand with hardware development, without data to substantiate its need. No doubt, the belief in the need for pictorials for CAI has held over from audio-visuals and the belief in the positive instructional effects of pictures.

A more experimental approach, more fully utilizing the distinct potential of CAI, has been described by Hammond (1971). He predicts that the ability of CAI to produce variable graphic feedback will enhance decisionmaking and diagnostic training. For example, medical students may learn the art of diagnosis using a probability approach. When presented with symptoms, the student generates graphic displays of how he works with the data, alongside displays generated by successful clinicians handling the same data. This procedure circumvents the right answer/wrong answer paradigm more likely to appear in other content areas. Other uses of interactive computer graphics include labor-management feedback (Balke, Hammond, & Meyer, 1973). However, no empirical evaluation of the effectiveness of interactive graphic presentation has been made.

Instructional Strategy: Reinforcement and Sequencing

Since its inception, CAI has been closely allied to learning theory, both because it resulted from the Skinner paradigm and subsequent programed instruction, and because it was a fruitful testing ground for learning theory hypothesis testing. The CAI presentation necessitates decisions concerning the presentation of material. Some of these options are central to old learning theory disputes. For example, the method of administering reinforcement requires several decisions; one such decision concerns the type of reinforcement that should be used. Existing CAI programs have often used familiarity with small children--"Very Good, Patti!" For adults, programs have provided randomly sampled, system-generated reinforcing phrases--"Fine. You're doing great," or "Exactly right!" Some other types of reinforcement must also be decided a priori, including decisions about feedback and reinforcement delays. Without presenting the mass of literature on the reinforcement issue, we can cite evidence that in some cases delayed reinforcement will enhance learning (Sassenrath & Yonge, 1968) but that the type of task may interact with the effectiveness of the delay (Lintz & Brackbill, 1966).

The type of reinforcement used may influence the subject's achievement motivation, which may in turn influence the effectiveness of the procedure. There is evidence that the effectiveness of high-incentive conditions (money bonus) is different from the effectiveness of low-incentive conditions. Bahrick (1954) found less incidental learning

under high-incentive conditions, a result that may generalize to the learning of detailed information--e.g., subjects who have less incidental learning may learn fewer details.

Decisions about the size of demonstration units and presentation length of lessons must also be made, although there is little research to address these two factors. In addition, one of the most controversial questions in educational research is whether to present rules followed by examples or to present examples that help the student to derive rules. Other sequencing problems include when and how to present difficulty levels.

Mayer and Greeno (1972) suggest that rule/example sequence effects are dependent on whether the goal places emphasis on using the rule (performance) or on more cognitive aspects (knowledge) such as formulating new rules, i.e., the extrapolative versus the interpolative needs of the tasks.

Additional cuing and sequencing effects have also been described. Low-ability subjects are reported to respond significantly better to programs using many instructional cues (highlights, arrows pointing, etc.), whereas higher ability subjects are more sensitive to the sequencing of material (Hall, 1971).

Other factors relevant to CAI include human factors elements such as size, marginality, and distribution of type, all of which may interfere with reading (Gregory & Poulton, 1970) and the accoustical environment, which may be distractive (Knirk, 1970). Both these factors may influence learning. Some material may elicit a credibility gap; an example is the psychological material presented by Fiks (1964), who reported subject mistrust of the psychological instructional material employed. Other media such as TV are more resistant to credibility gaps (Addis, 1970).

Programed Instruction (PI). Much of the research relevant to CAI instructional strategy has been derived from research using other techniques, particularly PI. Fiks (1964) made one of the most comprehensive evaluations of the effectiveness of PI when he presented material on space travel, auto safety, and psychology to visitors to the Indiana State Fair. Fiks manipulated feedback delay and also obtained a three-question, Likert-type attitude measure, as well as educational and demographic data. His results indicated a significant content-difficulty main effect. As the percentage of confirmations decreased, the number of errors increased. In addition, there were significant interactions on the overt-covert dimension in relation to attitude; subjects reported that they liked PI better when they were writing (overt) than when they were not (covert). Attitude toward PI did not appear to affect performance; however, a credibility gap for the psychology material was evidenced. A curvilinear relationship between education and feedback was hypothesized; the lowest educated subjects liked PI progressively more

as feedback was increased, and the more highly educated subjects displayed a reverse trend. Subjects also reported favoring complete rather than partial feedback. Fiks concluded that systematic population variance occurs with programed instruction.

Self-Pacing. As PI research continued, it became more evident that self-pacing alone could not account for all individual differences. Fry (1972) tried to determine which qualities of the self-paced instructional situation would influence performance. He pretested subjects for achievement (above and below the median on the SAT) and for inquisitiveness, using a battery of tests purported to account for 50% of the variance for "inquisitiveness" (Shulman, Loupe, & Piper, 1970). Material was then presented in one of four ways: (a) student controlled instruction (SCI), a self-paced method in which subjects were encouraged to ask questions; (b) a structured presentation that combined expert opinion and used the questions generated by the first group; (c) a random presentation; and (d) a control group of TI. Subjects were assigned on the basis of their aptitude and inquisitiveness scores to one of the four treatments. The subject matter was computers. High inquisitive/high aptitude (HI/HA) subjects did equally well on the SCI and random conditions and less well on the expert condition. Fry determined that this result was due to the challenge of working with random material and recommended that, in general, SCI be used for HI/HA subjects. HI/HA subjects performed best on the expert material, and about the same on SCI and random. Thus inquiry may be a significant factor in self-paced instruction.

Woodruff, Faltz, and Wagner (1966) reported that although initially PI was thought to compensate for individual variation, other variables such as personality, attitude, reading ability, and IQ significantly affected performance on PI. Subjects were grouped according to high, medium, and low ability derived by combining IQ, grade point average (GPA), and science grades. High-ability subjects made proportionately the fewest mistakes; in contrast to other groups, their mistakes were errors of nonresponse rather than incorrect responses. Several personality characteristics such as achievement need were also measured, using the Edwards Personal Preference Schedule and Gordon Personal Inventory factors (Cautiousness, Original Thinking, Personal Relations, Vigor). These factors were positively correlated with the number of correct responses per frame.

Additional Factors. Other research has indicated that course completion time for PI is significantly less than that for more traditional methods (Chrisman, 1970). Some researchers believe that PI is ideally suited for the application of learning theory principles. For example, Skypek (1971) determined two methods for teaching new words: Phase One, which maximized acquisition; and Phase Two, which maximized retention. These methods could easily be programed without losing continuity of presentation. Skypek's research reflects the synergistic relationship between learning theory research and CAI program development today.

Delayed retention studies have not necessarily shown that PI is more effective than other modes. Garrard (1969) manipulated PI, TI, and film when presenting material to nursing students. A multiple-choice test showed PI significantly better at immediate testing but evidenced no significant differences at delayed testing.

Summary

Little if any research exists that directly addresses the instructional effectiveness of graphics in CAI. Research that contrasts CAI with other media or other techniques (in order to evaluate graphic effectiveness) must be considered with caution. The apparent advantages of advanced audiovisual technology may be due as much to the inherent instructional design requirements as to graphic capabilities.

WHERE DO WE GO?

Two major conclusions can be drawn from the research review. First, it is clear that the addition of graphic instructional material does not guarantee an increase in instructional effectiveness. Although this point appears obvious, such an assumption underlies the bulk of the research reported and is responsible for a number of theories or propositions regarding selection of the "best" media and the design of displays for the presentation of graphic material. This same assumption may account for the paucity of research directly addressing the area of interactive computer graphics.

The second major conclusion is that although there apparently are conditions in which graphics may be an important adjunct to the instructional process, there is currently no systematic means of identifying these conditions. This situation exists because definitional and methodological differences make it difficult to do a cross-comparative analysis of research findings. Hence, the first step for future research in this area is to develop a framework that can assist in better structuring of research outcomes.

The Definitional Problem

Although the term "display" includes any method for presenting information (Kidd, 1962; McCormick, 1970), the emphasis on graphics restricts this term to visual displays. Unfortunately, the term "graphics" itself is not clearly defined. For distinguishing different presentation modes, however, certain categories emerge rather consistently.

At a minimum, a distinction is made between alphanumeric and other forms of information presentation (McCormick, 1970; Nawrocki, 1973). Alphanumeric presentations are those restricted to the use of character sets with a direct referent to linguistic information. In addition,

most human factors discussions of visual information distinguish between several forms of nonalphanumeric information, i.e., graphic information (Colson, Freeman, Mathews, & Stettler, 1974; Hitt, Schutz, Christner, Ray, & Coffey, 1961; Saul, 1954). In general, these distinctions fall into three clusters: special symbols with predesignated referents; graphs and charts indicating spatial-temporal relationships; and depictions of objects or events via representations with varying degrees of fidelity.

A cluster derived by factor analysis, based on cognitive ability, appears as part of Guilford's (1967) structure of intellect model. Guilford proposed a semantic, symbolic, and figural categorization scheme for information presentation. Hence, Guilford's model supports both an alphanumeric (semantic) and at least a dichotomous graphic (symbol and figural) distinction.

Based on the preceding discussion, the authors propose the following categorization scheme for visual presentations:

1. Alphanumeric--the presentation of information via a set of characters with direct linguistic referents, mutually agreed upon by a language community; and

2. Graphics--nonalphanumeric information presentation, to include

   a. Symbolic--character sets in which each character has a predesignated, but nonlinguistic, referent to a specified object or concept;

   b. Schematic--two-dimensional line representations of spatial or temporal relationships; and

   c. Pictorial--representation of objects or events, to include their relationships, but with the representation having some degree of fidelity to the physical characteristics of these objects or events.

These definitions are suggested as an initial step toward providing a baseline for future research and minimizing problems in semantics. Admittedly there is room for refinement of these definitions, and clearly many visual displays will combine features characteristic of more than one category. However, the evidence cited previously suggests that the four-category scheme is a reasonable compromise between several alternatives. In any case, research would benefit from explicit definitions of terms such as graphics and visuals.

Research Framework

Research on instructional graphics should take into account the three major variables identified in this report: Task, Content, and Individual Differences. In terms of Task and Content, a number of taxonomies exist, albeit on a descriptive level. A promising taxonomy that combines features derived from previous efforts is that of Merrill and Boutwell (1973).

Merrill and Boutwell developed a taxonomy which considers both the content and task (behavior) dimensions (Figure 2). It is likely that a number of ambiguities in the area of instructional graphics would be clarified by adopting this taxonomy as a means for comparative analysis of future research results.

The most promising approach to determining the influence of individual differences is the Aptitude by Treatment Interaction (ATI) design. Those population characteristics which appear to have potential predictive value have been discussed in the ATI section of this review. Other critical characteristics remain to be determined, and experimentation that correlates a number of aptitude measures to the dependent variables will be necessary prior to true ARI experimentation.

Finally, the dependent measures chosen should be as inclusive as possible. The realism research indicates that overall performance will be difficult to interpret if visual and verbal task components have not been isolated. Moreover, the same research suggests that delayed retention measures may reduce or eliminate effects obtained using measures of immediate retention. A systematic research program is underway within ARI, based on the framework described.

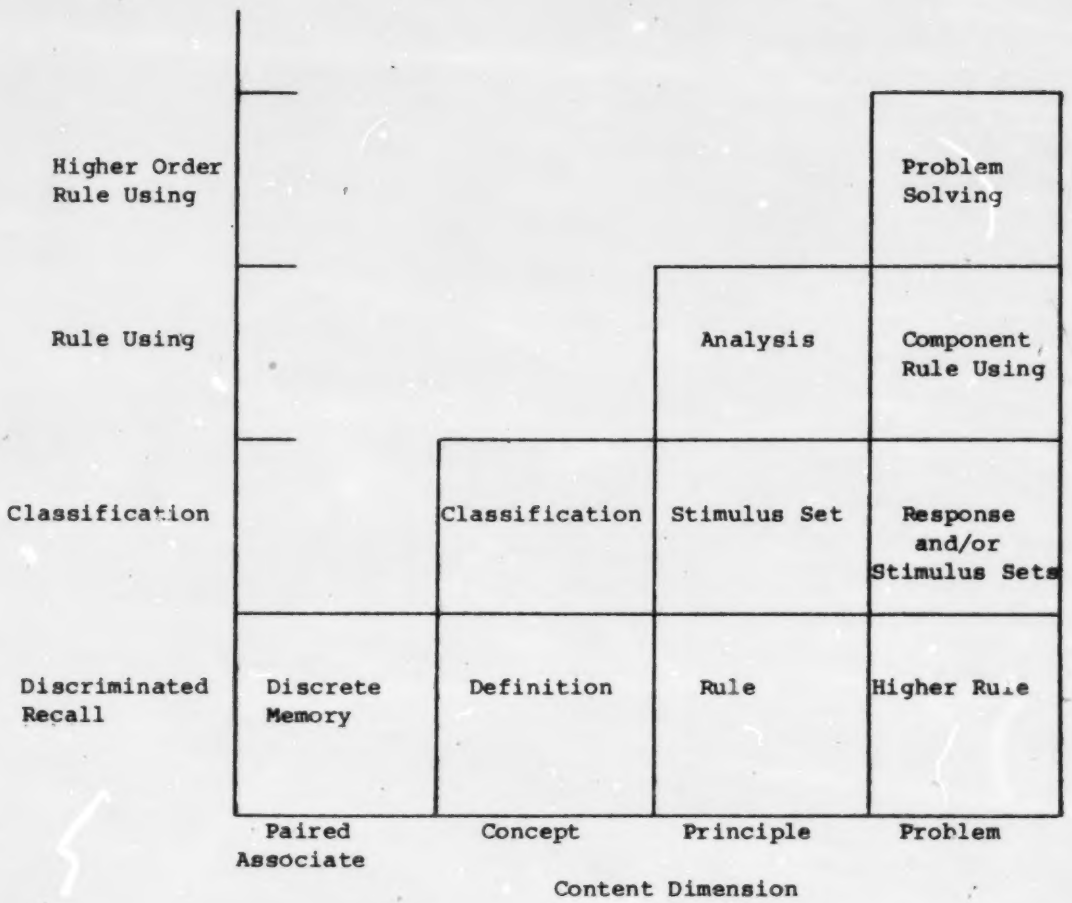

Figure 2. Task by Content taxonomy
(adapted from Merrill and Boutwell, 1973).

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